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ABSTRACT

This discussion of dyslexia addresses the popular view that reading disability in children with dyslexia is caused by dysfunction in visual processing. Several visual deficit theories are presented and challenged. In addition, evidence for and against specific hypotheses is reviewed and evidence is presented that supports the likelihood that reading disability is caused either by deficiencies in one or more aspects of linguistic functioning or by a specific disorder in visual/verbal integration. (TJ)

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Visual Processing Deficiencies in Poor Readers: A Critique of Traditional Conceptualizations of the Etiology of Dyslexia

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Visual Processing Deficiencies in Poor Readers: A Critique of Traditional Conceptualizations of the Etiology of Dyslexia[1]

Introduction

Developmental dyslexia, or specific reading disability,[2] as it is also called, is a puzzling disorder of childhood characterized by severe impairment in the decoding of printed words. This disorder has been found to occur, in spite of general capability in children who are normal in other respects. Such youngsters, by definition, support no intellectual deficits, sensory acuity problems, severe brain damage, gross physical disabilities, or serious emotional and social disorders, and their achievement difficulties have not ostensibly been hampered by cultural or socio-economic disadvantage, and/or inadequate exposure to the material to be learned (Rabinovitch, 1959).

This paper will address the popular view that reading disability in children of this description is caused by dysfunction in visual processing. Several variations of this conceptualization will be presented and challenged. Evidence for and against specific hypotheses will be reviewed and our discussion will provide some support for the likelihood that reading disability is caused, either by deficiencies in one or more aspects of linguistic functioning or by specific disorder in visual-verbal integration.

Visual Deficit Theories

Developmental dyslexia has been most often attributed to dysfunction in visual perception, and by extension visual memory. This point of view has been the dominant theme in the study of reading problems in young children since before the turn of the century when W. Pringle Morgan (1896) initially described specific reading disability in an otherwise normal

adolescent. Morgan believed that the disorder was caused by structural damage to the "visual memory center," a position similar to the one held by his contemporary Hinshlewood (1900).

However, the most influential proponent of the perceptual deficit explanation of dyslexia was Orton (1937), who suggested that reading disability (or as he termed it "strephosymbolia") was caused by visual-spatial confusion stemming from delayed lateral dominance for language. Perceptual disturbance was said to be especially evident in the form of apparent distortions in perceiving similar appearing letters and words ("seeing" b as d or was for saw), as well as in orientation and sequencing errors sometimes observed in the writing of dyslexics ("mirror writing"). Orton believed that such anomalies occurred because of the failure to suppress one of two symmetrical "engrams" stored in each of the hemispheres, owing to the inability to establish hemispheric dominance. He considered such errors to be of cardinal importance in establishing a diagnosis of dyslexia, and suggested that they would become manifest only in the processing of symbolic stimuli such as letters and words.

Several variants of Orton's theory appeared subsequently, most to some extent influenced by his writings. For example, Bender (1956) suggested that specific reading disability was the result of disturbances in visual form perception and figure-ground abstraction, associated with a neurological maturational lag. Drew (1956) adopted a similar position.

Hermann (1959) attributed dyslexia to a congenital disposition toward spatial confusion, and apparently believed that one's "sense of direction" was an inborn entity supported by specific neurological mechanisms rather than a learned phenomenon determined by relative coordinates. He also

believed that directional confusion would be manifested, not only in the poor reader's attempts to process linguistic symbols, but also in processing symbolic material of any description, such as numerals and musical notations.

A number of authors (e.g., Kephart, 1960; Cruickshank, 1968; Frostig and Maslow, 1973) have associated reading problems with perceptual deficits more basically caused by motor disability leading to deficient "perceptual-motor" integration. And some (Getman, 1962; Anapolle, 1967) suggest that perceptual impairments are caused by structural disorder of the eyes.

Special mention might also be given to Birch's (1962) suggestion that dyslexia, in some children, may be the result of the failure of the visual system to become the dominant modality. This author pointed out that, during the course of normal development, the teleoreceptor systems come to supercede the proprioceptive systems, which in large measure structure attentional processes in infants and very young children. Thus it was hypothesized that such development may not take place in some poor readers, thereby causing attentional and figure-ground difficulties in processing visual stimuli. Birch (1962) also proposed that some poor readers might be hampered by a specific deficit in learning visual part-whole relationships, although the nature of this disorder was not made explicit.

Two more recent versions of the perceptual deficit explanation of reading disability are also worthy of mention. Stanley and Hall (1973) suggest that dyslexics may be subject to difficulties in form perception and other visual distortions because of abnormally persistent after images, the duration of the after image in normal individuals being anywhere between

250 and 300 milliseconds. These authors have presented evidence which suggests that the duration of the visual memory trace in poor readers is approximately 50 milliseconds longer than that of normal readers and this, they speculate, may interfere with and "mask" incoming stimuli.

Finally, Mason (1975) theorized that poor readers, while most likely intact with respect to form perception and spatial orientation, have difficulty in "perceiving" the spatial locations and spatial redundancies of letters in words. Redundancy, in the occurrence and location of given letters, is characteristic of all orthographies based on an alphabet, and the presumption is that poor readers literally do not "perceive" such redundancy. Interestingly, enough, this hypothesis is extended to non-alphabetic symbols as well, and the author suggests that perception of given shapes (such as letters), and perception of the recurrent appearance of those shapes, may be mediated by different brain regions (Mason and Katz, 1976, p. 347).

The above theories, while somewhat disparate, share the same central theme — that is, that poor readers are deficient in processing visual information, especially information of a symbolic nature. However, in my opinion, perceptual deficiency is an unlikely source of specific reading disability, at least insofar as such deficiency is conceptualized as the result of a basic organic disorder causing disruption or distortion of the distal stimulus. This seems to be true on logical as well as on theoretical and empirical grounds. Let me be more specific.

First, as pointed out earlier by Benton (1962), if, indeed poor readers were subject to the curious visual anomalies that Orton and others have suggested characterize this group — that is, optical reversibility

spatial confusion, figure-ground dysfunction and the like — then such disorders should be apparent in many other functions in daily living. Yet there is no evidence that this is true. Moreover, the suggestion made by Orton (1937) that perceptual distortions should occur only in processing symbolic material such as printed letters and words seems counterintuitive, particularly since there are more parsimonious explanations of such disorder. For example, I will present results below which indicate that the letter orientation and sequencing errors sometimes observed in poor readers, and long thought to constitute compelling evidence for inferred perceptual deficits in such children, are not primary manifestations of spatial and directional confusion, as suggested by Orton and others, but are in fact linguistic intrusion errors caused by dysfunction in verbal mediation.

Secondly, I quite frankly doubt the contention that poor readers are spatially and directionally confused, as a result of some congenital or developmental disorder of basic constitutional origin. This view carries with it the assumption that "directional sense" is an absolute function that is determined by neural mechanisms especially designed for programming direction and orientation. This seems to me to be at variance with parsimony. Indeed, it would appear that orientation in either two or three dimensional space is a relative rather than an absolute function that emerges largely because of relationships that are acquired, and not because of an inborn "sense of direction." We program proper orientation and direction by storing information that juxtaposes specific environmental and/or representational coordinates, most of which are quite arbitrary in nature. Thus written English is processed from left to right, while Hebrew and Arabic are processed from right to left, but directionality in such instances is learned, not innate as implied in

spatial deficit theories of reading disability.

Third, rather than suggest that the poor reader's inaccuracy in discriminating letters and words is attributable to organically derived malfunction in perception, I think it would be more accurate to suggest that visual discrimination problems are secondary manifestations of more basic dysfunction in coding the linguistic components of printed words, which in turn, leads to inefficiency in attending selectively to information that will facilitate critical distinctions. To be more specific, the assumption is made that the linguistic features contained in printed words constitute implicit "cues" or mnemonics which both assist and monitor the discrimination process. Thus, the child who is sensitized to the sound and articulatory differences in similar appearing letters and words (e.g., b d, was, saw, not, ton), and, in the case of the words, knows something about their meanings and uses in sentences, has a considerable amount of (verbal) information that aids him in programming the correct orientations and sequences characteristic of those configurations. On the other hand, the child who has difficulty, either in acquiring, or accessing such linguistic detail, will also have difficulty in becoming sensitized to subtle differences in the appearance and structure of letters and words, and will therefore be inclined to process their featural characteristics globally and inefficiently. Thus he will be chronically disposed toward making the kind of positional and sequential errors that prompt the suspicion that he supports organic disorder resulting in perceptual deficiencies of the types variously proposed in the literature.

The above brings me to a final point I wish to make, in contention with the perceptual deficit explanations of specific reading disability.

In my estimation, reading difficulties are associated primarily with deficiencies or dysfunction in one or more aspects of verbal processing; or perhaps with a specific disorder in visual-verbal integration, these two possibilities not being mutually exclusive. I am inclined to agree with those who suggest that reading is basically a linguistic skill (Goodman, 1965; Smith, 1971; Mattingly, 1972 Liberman and Shankweiler, 1977), and believe that a careful analysis of the process will reveal that it taxes the visual and linguistic systems unequally. For one thing, this function requires only discrimination and recognition of the visual components of words, but recall or reproduction of their verbal components, recall by definition involving the recollection of more detailed information than recognition (Underwood, 1972). In other words the problem lies in verbal memory not in visual memory, since in reading, the visual system is not required to do a great deal of remembering. Concretely, the difficulty experienced by poor readers is not in distinguishing the visual features of b as opposed to d, but in remembering which one is called "bee", and which is called "dee."

We can reinforce the point made above by underscoring the fact that word decoding, involves the processing of much more verbal than visual information, given that each printed word contains three featural categories that have reference to its linguistic properties (semantic, syntactic, and phonologic) and only two that have reference to its visual characteristics (graphic and orthographic). Furthermore the redundant and invariant nature of English orthography actually allows for considerable economy in processing the visual features of printed words, in that certain letter combinations occur with high frequency in predictable spatial locations (e.g., qu, tion, ing). The normal reader soon learns to capitalize on this aspect of

(printed) English in the interest of perceptual efficiency (Rosinski and Wheeler, 1972). However, the child who has difficulty in learning to associate the visual and linguistic counterparts of printed words will not readily become aware of orthographic redundancy, and this results in implicit tendencies to process either too little or too much visual information, rather than attend, selectively, to relationships that effect critical discriminations. Thus, it would seem that reading is especially vulnerable to deficiencies in one or more aspects of learning involving a verbal component. It is also likely, that difficulties in such learning would eventuate in the failure to develop efficient strategies for processing the graphic and orthographic components of printed words, thereby creating the impression that visual discrimination errors are the result of perceptual disorder in the sense in which this term is typically employed.

Support for the position taken above is both direct and indirect. Direct support comes from studies which yielded no differences between poor and normal readers on measures of visual processing when the effects of group differences in verbal ability have been controlled. Indirect support comes from recent studies that have reliably demonstrated reader group differences in various aspects of linguistic functioning (Vellutino, 1977; Vellutino, in Press). However, the remainder of this paper will be primarily concerned with the results of studies evaluating visual deficit theories of reading disability. I will initially review and critique research evidence that has been offered in support of such theories and, then review a number of studies issuing from our own laboratory, the results of which constitute the primary basis for our position.

Research Evidence

Perhaps the procedures most often employed to evaluate the possibility that reading difficulties may be associated with perceptual disorder are the figure-drawing and the visual-matching tests. This is true with respect to both clinical practice and laboratory research. The wide spread use of figure-drawing tests for this purpose is an outgrowth of the developmental studies conducted some time ago by Schilder (1944), Gesell (1952) and Bender (1956, 1957), this practice being later reinforced by advocates of motor deficit theories of learning disability (e.g., Kephart, 1960; Cruickshank, 1972; Frostig and Maslow, 1973). The implicit assumption associated with the use of such tests is that deficient visual-motor integration is indicative of deficient neuro-motor maturation, from which dysfunction in perceptual organization and form perception can be inferred.

The visual matching test is, of course, a face valid measure of form perception, requiring only that the child separate a target stimulus from several distractors and match it with a standard.

Distractor items typically appear in a horizontal array on the right side of the stimulus and are most often presented with the standard in full view. It would therefore seem to be a straightforward approach to the assessment of perceptual functioning.

A number of studies have, in fact, reported significant differences between poor and normal readers on tests of visual-motor integration and shape matching (e.g., Smith, 1928; Goins, 1958; Silver and Hagin, 1960; Lovell, Shapton and Warren, 1964; Lovell, Gray and Oliver, 1964), and still others have found moderately high correlations between scores on these respective measures, administered to kindergartners, and scores on

tests of reading achievement administered in later grades (de Hirsch, Jansky and Langford, 1966; Jansky and de Hirsch, 1972; Satz, Friel and Rudegair, 1974a, 1974b). These particular studies represent some of the most widely cited of those that have offered support for the perceptual deficit explanation of reading disability, and have, over the years been largely responsible for maintaining this hypothesis.

It seems paradoxical that perceptual deficit theories of reading disability have derived their primary support from investigations that have employed the figure-drawing and matching tests as measures of form perception, since these instruments can, at best, yield equivocal results when used for this purpose. The figure-drawing test is, of course, confounded by individual differences in motor development, conceptual ability, and experience, not to mention the possibility that the copying of figures is a specialized skill or talent that is characterized by a wide range of individual differences. It cannot therefore be viewed as a measure of visual perception.

Furthermore, the basic premise promoting the use of figure-drawing tests as measures of perceptual functioning is debatable. Tradition notwithstanding, there is no compelling reason to believe that motor deficiencies, or dysfunction in visual-motor integration has any influence whatsoever on visual discrimination and visual form perception. Indeed, logic would have it otherwise. As pointed out in Gibson and Levin (1975), there are many children afflicted with even very severe motor disabilities who become quite literate in spite of such handicaps, children with varying degrees of cerebral palsy being cardinal examples. It is therefore doubtful that figure-drawing tests will tell us anything about reading disability. In fact, the results of studies employing such measures to

evaluate perceptual deficit explanations of this disorder are not only questionable, but will most likely prove to be of little moment.

The visual matching test as a measure of form perception is also questionable, at least as regards the use of the multiple alternative format typically employed in both research and clinical study. It will be recalled that such measures usually present the standard stimulus on the left, and the distractor and target items on the right. Given that this procedure requires the systematic comparison of target and several alternatives, we may reasonably suggest that successful performance relies more heavily upon cognitive functions such as memory and coding ability, than it does upon basic visual discrimination skills. Success on matching tests would also appear to be influenced by experience, particularly experience that develops the type of "work habits" that may dispose a child to systematic and strategic scanning of the amount of visual information included on tests of this sort. Calfee (1977) has provided some evidence in support of this contention. In a series of related studies comparing single versus multiple alternative formats for visual matching, it was found that the single alternative procedure reduces the error rate to negligible proportions, even in very young (kindergarten) children. Calfee (1977) has also demonstrated that on the more traditional matching (multiple distractor) procedure, the probability of error increases as the location of the correct match moves farther to the right. He therefore suggests that the match to standard tests commonly employed to measure visual discrimination (e.g., on reading "readiness" tests), may be confounded by visual short term memory and coding ability, both of which are called into play when the child attempts to hold the standard in mind as he searches the distractors for the correct match.

Of additional interest is Calfee's (1977) observation that measures which require the visual matching of letters and words, lend an advantage to kindergarten children who already have some degree of skill in reading, thereby accounting for the positive correlations observed between tests of reading ability administered in first grade, and performance tests of visual matching administered earlier. On the other hand, this correlation was found to be negligible when a single alternative format was used to assess visual discrimination ability. Calfee (1977) concludes from these findings that visual discrimination skills account for a very small proportion of the variance in reading ability in beginning readers.

It should be clear from the above, that the results of investigations evaluating form perception in poor readers through the use of visual matching procedures can by and large, be challenged given that most employed the standard format (multiple distractor), which, of course, does not control for memory, coding strategies, and in some instances, experiential factors as well. More importantly, the data again emphasize the hazard in ascribing perceptual deficiencies to children who perform poorly on visual discrimination tasks, since their performance may be more accurately ascribed to impairments in higher order cognitive functions, and/or experience of the type necessary for successful performance on such tasks.

The positive findings reported in the studies referenced above are also equivocal because of sampling and interpretive problems. As regards the first of these difficulties it will be sufficient to point out that in all but two of the studies mentioned (Lovell, Shapton and Warren, 1964; Lovell, Gray and Oliver, 1964), there were no adequate controls for possible confounding due to socio-economic factors. With respect to the second problem, it should be noted that poor readers, in all of these investigations,

were less proficient than normal readers on a variety of tasks, both verbal and non-verbal, and not exclusively on measures of perceptual and perceptual-motor functioning. This suggests that the subjects evaluated were characterized by general learning difficulties, rather than specific learning disability resulting from perceptual disorder.

More direct evidence that visual-motor dysfunction is not a significant correlate of reading disability, is derived from several better controlled studies which found no significant differences between poor and normal readers on tests of visual-motor functioning, and visual perception (Nielson and Ringe, 1969; Symmes and Rapoport, 1972; Vellutino, Pruzek, Steger and Meshoulam, 1973; Vellutino, Smith, Steger and Kaman, 1975). Noteworthy,is the fact that the sampling procedures employed in these investigations were much more stringent than those employed in the studies referred to above. This of course reinforces the suggestion that observed group differences on the measures in contention, may have been caused by a variety of extrinsic factors, a likely possibility in the case of heterogeneous, or ill-defined samples.

While the majority of studies evaluating adequacy of form perception in disabled readers have relied upon indirect methods of assessment, such as figure-drawing and matching tasks, a few investigations have recently attempted to more directly assess this function, by comparing poor and normal readers on measures which evaluate visual discrimination during the initial stage of visual processing, that is during the first 300 milliseconds following termination of stimulus exposure. This duration represents the approximate longevity of the visual after image, its brief existence, in effect, placing a natural constraint on the amount of time available for visual analysis and synthesis. Thus studies which assessed initial stage

processing in poor and normal readers, employed experimental methods which limit the duration of the after image, thereby insuring that visual discrimination was based upon direct analysis of the stimulus, rather than coded representations of its characteristics. A brief review of a representative sampling of these studies follows.

Stanley and Hall (1973) tested the hypothesis that disabled readers take longer than proficient readers to transfer visual information from sensory to short-term storage. Of particular interest was the duration of the visual after image or "memory trace." A protracted memory trace could conceivably disrupt form perception by creating a natural "mask" for incoming stimuli. Previous research (e.g., Gummerman and Gray, 1972) had demonstrated that trace duration is greater in children than in adults, and this prompted the suggestion that dyslexics may be characterized by an abnormally persistent sensory image, as a consequence of developmental immaturity.

This suggestion was tested employing a technique devised by Erikson and Collins (1968). These authors found that presentation of two halves of given figures (e.g., N and O) in very close succession (e.g., 20 milliseconds) creates the impression of a composite (NO), because of overlapping after images. However, at interstimulus intervals (ISI) of sufficiently long duration, the constituents of the composite are perceived separately. The ISI at which the figure is no longer seen as a composite therefore becomes a convenient measure of trace duration.

This procedure was employed with dyslexic and normal readers between 10 and 12 years, presenting subjects with the word NO, a cross, and a cross surrounded by a square. Employing the method of ascending limits, which is an absolute judgement procedure, subjects were required to indicate the

point at which they perceived the "break up" of a given figure. The dependent variable in this study was the ISI at which the two halves of the composite figure appeared to be separated. Subjects were also asked to identify the figures presented. It was found that the mean ISI for reporting the separation was greater in poor than in normal readers. The poor readers also took longer than the normal readers to identify each figure.

In a second phase of this study, the authors gave the same children brief presentations (20 milliseconds) of single letters for identification, followed by a masking stimulus comprised of a dot matrix. Employing 20 millisecond intervals between presentations of the target letter and the mask, it was found that the poor readers required a significantly longer ISI between the letter and the mask for correct identification. The authors concluded that both duration of the visual image and rate of transfer to short term memory is greater in dyslexics than in normal readers. They suggested further that a memory trace of extended duration may interfere with subsequent stimulation and thus perception of incoming stimuli.

The above results are interesting, but questionable on both methodological and interpretive grounds. The most obvious weakness of the study is the use of an absolute judgement task to evaluate trace duration in that it is an indirect and highly subjective measure that may not yield reliable results. It is entirely possible, for example, that the poor readers in this study had longer ISI's because of a conservative response strategy, rather than any basic deficiencies in trace duration. In other words poor readers, who, generally speaking, may be characterized by greater uncertainty in performance situations than normal readers, may

have been more hesitant than the normals, in reporting what they saw. That this is a reasonable interpretation is suggested in the finding of no differences between reader groups in two separate studies (Stanley, 1976; Arnett, 1977) evaluating trace duration and rate of processing, employing a forced choice method of discrimination, rather than the absolute judgement procedure used by Stanley and Hall (1973).

Furthermore, it is not surprising to find, as did Stanley and Hall (1973), that poor readers take longer than normal readers to identify letters. Poor readers, by definition, are characterized by uncertainty in letter and word identification, even under optimal stimulus conditions. Thus, under less than optimal conditions — for example in very brief tachistoscopic exposures — poor readers may well be indecisive, thereby inflating the ISI from trial to trial. In any case the results of the Stanley and Hall (1973) study are equivocal and the authors' interpretations of their findings is debatable.

The suggestion that poor readers are characterized by dysfunction in initial stage processing is further equivocated by the results of two other studies which have recently appeared in the literature. Briefly, Fisher and Frankfurter (1977) evaluated trace duration in one group of poor readers (age 10 years) and two groups of normal readers, one matched with the poor readers for age, and another matched for reading level. A backward masking paradigm was employed to evaluate trace duration, and varying numbers (two, four and six) of upper case letters served as the stimuli. The masking stimulus was a jumbled group of letter fragments, presented immediately after a 200 millisecond exposure of the target stimulus. The dependent measures included number of letters correctly identified, and their exact spatial locations. All subjects were compared

under both mask and no mask conditions.

Poor readers generally performed as well as the children in both normal reader groups under both stimulus conditions. In as much as the masking condition did not affect the poor readers more adversely than the normal readers, it was concluded that trace duration is comparable in both groups. The results are also contrary to the view that reading disability is associated with deficiency in form perception.

Finally, Morrison, Giordani and Nagy (1977) compared initial stage processing and short term memory functions in deficient and able readers in sixth grade (age 12 years), employing a variant of the partial report technique initially devised by Sperling (1960). Each subject was presented with a circular array of three sets of eight visual forms for brief exposures. Stimuli included upper case letters, as well as geometric and abstract forms. Each array was exposed for 150 milliseconds, followed by a teardrop indicator presented at varying delay intervals from 0 to 2000 milliseconds. The indicator appeared directly under the space in which a given form had been located, and the subject's task was to report the particular item that previously occupied that space. It was anticipated that a perceptual deficit would be associated with reader group differences on presentations between 0 and 300 milliseconds, while a memory or decoding deficit would be associated with group differences on presentations above 300 milliseconds. Contrary to the perceptual deficit hypothesis, poor readers performed as well as normal readers on exposures below 300 milliseconds but not as well on exposures above this figure. It was therefore concluded that poor readers are characterized by deficiencies in short-term memory and encoding, rather than dysfunction in form perception.

The results of the few studies available evaluating initial stage processing in poor and normal readers are conflicting, and further research is obviously needed to clarify questions that have been raised. However, we doubt, on logical grounds, the suggestion that reading disability is associated with deficient form perception caused by an unusually protracted after image, as suggested by Stanley and Hall (1973). Suffice it to say, in support of our contention, that such an anomaly, even if characteristic of poor readers, would not likely constitute a serious impediment to letter and word perception, since a child so impaired, would no doubt learn to adjust the amount of visual information he attempts to process in reading, and the rate at which he processes such information, so as to insure clear vision and reliable perception.

Furthermore, a trace persistence theory of reading disability, or for that matter, any deficit theory which emphasizes deficiency in form perception as a basic cause of the disorder, cannot readily account for the majority of word decoding errors made by poor readers, word substitutions (e.g., saying /Kitty/ for cat, /was/ for saw, etc.) and phonetic mispronunciations (saying /shop/ for chop) being cardinal examples. Such inaccuracies would seem to reflect impaired verbal processing rather than deficiencies in form perception. We are therefore confident that such theories will ultimately be discarded. However, we fully acknowledge the utility of additional study of initial stage processing in poor and normal readers, if only to reconcile conflicting results which have appeared in the literature, since this approach clearly permits a more direct analysis of the formation of visual images than do traditional methods that have been employed.

As noted earlier, the visual deficit explanation of reading disability

has several variants which have been proferred. In addition to deficiencies in form perception, this disorder has been attributed to spatial and directional confusion, as well as dysfunction in figure-ground perception, speed of visual processing, visual memory and perception of spatial location. A brief and selective review of laboratory studies evaluating these possibilities follows.

Perhaps the most common theme among perceptual deficit theories of reading disability is that dyslexics are characterized by deficiencies in processing spatial information (Orton, 1937; Hermann, 1959). Such difficulty is said to be manifested in "orientation" and "sequencing" errors in oral reading and writing, inability to establish a left-right directional set, difficulty in differentiating the two sides of the body, and like problems. We have already raised a number of questions about the logic behind this theory, but can point out, in addition that there are very few studies which have directly assessed its validity (Benton, 1962, 1975). Such studies include tests of left-right discrimination (e.g., Harris, 1957; Belmont and Birch, 1965) and evaluation of positional and directional errors in reading and writing (Lyle, 1969; Liberman, Shankweiler, Orlando, Harris and Berti, 1971). A general finding in these investigations was that poor readers had more difficulties than normal readers in applying the correct verbal labels to configurations which differed only with respect to their spatial properties. While some authors interpret such findings as evidence for spatial confusion in poor readers, not all do so.

For example Liberman et al. (1971) found that confusions in orientation (b/d) and sequencing (was/saw) accounted for only twenty-five percent of the total number of oral reading errors made on lists containing a high proportion of words designed to elicit spatial inaccuracies.

In addition, these two types of errors were not highly correlated, as would be predicted by the spatial deficit theories of reading disability. Indeed, the author suggested that such inaccuracies were, in fact, linguistic intrusion errors (mislabeling) rather than perceptual distortions, an interpretation which may also apply to observed differences between poor and normal readers in naming the two sides of the body (Harris, 1957, Belmont and Birch, 1965).

To continue, a study by Wechsler and Hagin (1964) evaluated the spatial deficit theory of reading disability in poor and normal readers in grades one and three. Subjects were compared on the matching of novel figures shaped like a lamb chop and differing only in orientation. Reader groups were identified by teacher judgement in first grade, and a group test of reading achievement in third grade, but no other description of the sample was provided. The matching test involved a standard and six alternatives, and was administered both with the standard remaining in full view, and exposed for brief (3 second) durations.

The poor readers did not perform as well on this test as the normal readers, although the magnitude of group differences was greater when the standard had to be memorized. In addition, significant correlations were found between the matching task and the reading measures, but only for children in first grade. The authors concluded that spatial orientation ability is an important skill for "reading readiness" and that poor readers may be deficient in this function.

I am inclined to doubt this interpretation of these findings for several reasons. Aside from the fact that achievement criteria in this study were weak, and the nature of the sample was not apparent, there was no documentation of the fact that the poor readers tested were actually

characterized by a high incidence of "spatial confusion" errors in reading and spelling. In addition, it should be apparent, from our previous discussion, that the matching task employed in the study may have inordinately taxed the visual information processing devices of the children in this study, unless they were sensitized to the need to systematically search for and deliberately code subtle differences in similar appearing figures — in this case — differences only in spatial orientation. To infer that poor readers, who were not sensitive to such differences, were "spatially deficient" (when this term implies a basic neurologic dysfunction or developmental immaturity), is perhaps to have violated parsimony, since group differences may have been due to experiential rather than constitutional factors. In fact, it is quite conceivable that success in reading becomes the occasion for awareness of the significance of positional and directional constancy, which of course would imply that poor achievement in reading would impede the development of such awareness. These findings therefore afford no convincing evidence that disabled readers suffer from spatial confusion, which appears to be also true of other studies offering support for this point of view (Benton, 1962; 1975). Indeed, we will present evidence below which substantiates our belief that this hypothesis is invalid.

That poor readers may be characterized by deficiencies in figure-ground perception was evaluated in three studies comparing disabled and normal readers on tests of the ability to educe simple figures embedded in complex visual arrays (Silver and Hagin, 1960; Goetzinger, Dirks and Baer, 1960; Lovell, Gray and Oliver, 1964). While the disabled readers performed below the level of normal readers on embedded figures tests in each of these studies, the results cannot necessarily be taken as support for the

hypothesis in question. We might point out initially that in one of these investigations (Silver and Hagin, 1960), the constitution of the sample was questionable in that there was no control for such variables as emotional disturbance and socio-cultural differences. Thus reader group disparities may have been due to extrinsic factors. And while the samples in the other two studies were better defined, their results were inconsistent in that poor readers performed as well as normal readers on some measures of figure-ground perception and not as well on others. Thus the reliability of the findings is in doubt.

However, we can also question the results of these studies on interpretive grounds. Analogous to a similar point made above, it is possible that poor readers, in part because of protracted failure in reading, have not acquired appropriate "orienting attitudes" that would allow them to process patterned information effectively. It would seem that success in abstracting embedded figures depends in large measure upon the development of an implicit tendency to search for ordering principles, and invariant relationships that may facilitate discrimination and perceptual organization economically and efficiently. We refer here to a perceptual "attitude" or disposition that is acquired with experience in processing complex visual material (Gibson, 1969, 1971) — experience which gradually increases one's ability to filter information by discovering the bases on which distinguishing relationships become salient, or "figure" is abstracted away from "ground." It is likely that the child who achieves in reading has acquired such an attitude, perhaps as a result of general experience, but maybe even as a partial consequence of his experience in reading. This would seem to be a plausible suggestion, considering the fact that the reading process provides ample opportunity for acquiring the

heuristics necessary for processing patterned information. Vernon (1971) makes a similar suggestion.

Consistent with this possibility are the results of respective studies conducted by Gottschalk, Bryden and Rabinovitch (1964) and by Olson (1970) in which it was found that the ability to systematically scan a complex visual array did not emerge before age six, the approximate time at which the child begins to learn to read. Thus it is entirely possible that some of the skills that are acquired in learning to read transfer positively to performance in abstracting embedded figures.

In any case, reader group differences on an embedded figures test does not necessarily imply that poor readers are perceptually deficient in the sense in which this term is typically employed, given that there are plausible alternatives to this interpretation, and, especially since the results on which it is based are equivocal.

While the majority of studies evaluating perceptual deficit explanations of reading disability have incorporated the assumption that poor readers are characterized by dysfunction in visual analysis and synthesis, even under optimal stimulus conditions, some authors have suggested that perceptual deficiency might not always be apparent in such children, except under stimulus conditions which emphasize speed and economy of visual processing. Thus a few investigations (e.g., Doehring, 1968; Katz and Wicklund, 1971, 1972) have compared poor and normal readers on match to standard and visual search tasks under timed conditions, reporting that the performance of poor readers was below the level of normal readers under such conditions. Space does not permit a detailed account of each of these studies, but it should be noted that their results are equivocal on methodological grounds. Especially problematic was the fact that in all three

investigations, subjects were compared on the high speed scanning of letters and words. This, alone, questions the findings since these materials are known to be problematic for poor readers. On the other hand the study by Doehring (1968) also compared these groups on the processing of non-verbal material. However, the reliability of Doehring's results are in doubt because poor and normal readers did not consistently differ on these measures, or for that matter on many of the verbal measures presented.

A second problem which characterized these investigations inheres in their use of traditional visual matching and visual search paradigms, which, as pointed out earlier, confound perceptual with memorial factors. This was particularly true of the Doehring (1968) study, which often involved visual search for a target among a very large number of distractors. Efficient feature detection in such instances would necessarily require the rapid coding of the featural characteristics of the target or standard stimulus, which obviously entails more complicated cognitive processing than does simple form matching.

This brings me to the third methodological problem in the studies in question, and that is that they did not attempt to control for the possibility of reader group differences in verbal encoding ability. Since, the tasks employed in these studies may have involved visual memory as well as visual discrimination, as noted above, dysfunction in the synthesizing and coding of visual stimuli may have accounted for performance deficits in poor readers, rather than perceptual disorder.

A number of studies which compared dyslexic and normal readers more directly on visual memory are characterized by similar difficulties. I refer, specifically, to a series of investigations conducted by Lyle and Goyen

(Lyle, 1968; Goyen and Lyle, 1971a, 1971b, 1973; Lyle and Goyen, 1975). In these investigations, dyslexics between the ages of six and nine years were found to be less proficient than normal readers on short term visual memory for both verbal and non-verbal material presented in match to standard formats and involving both immediate and delayed recognition. The authors generally inferred from these results that poor readers are characterized by perceptual deficiencies. Yet they did not control for possible confounding by virtue of reader group differences in verbal encoding ability, as in the studies discussed above. That this may be a problematic aspect of their findings is suggested in other results obtained by these same authors.

Briefly Lyle and Goyen (1969) found no substantial differences between poor and normal readers on a measure of spatial reasoning (Block Design subtest from the WISC), using the same subjects who manifested difficulty on a memory for designs test in the study reported by Lyle (1968). These findings belie the perceptual deficit interpretation of reader group differences on tests of visual memory observed in the other studies reported by these authors, and provide indirect support for the possibility of verbal coding deficit as the source of these differences. This suggestion is reinforced by the results of yet another investigation by these authors (Goyen and Lyle, 1971b), in which it was found that poor and normal readers did not differ on a measure of visual association learning. The latter finding obviously implies that the groups did not differ either in visual perception or visual long term memory. We will present results below which are consonant with this finding.

Finally, we indicated earlier that a relatively new version of the perceptual deficit explanation of reading disability has appeared in the

literature suggesting that poor readers are deficient in "perceiving" the redundancies in the spatial location of the letters in English words, but have no difficulty in perceiving their shapes, contrary to the more traditional point of view (Mason, 1975; Mason and Katz, 1976). In support of this hypothesis, Mason and Katz (1976) demonstrated that poor readers took longer than normal readers in locating IBM characters in a spatially redundant array, but did not differ in detecting spatial location in non redundant arrays employing the same characters. Because this difficulty was manifested with both alphabetic (Mason, 1975) and non-alphabetic material (Mason and Katz, 1976), the authors concluded that the problem may transcend the particular relationships involved in learning to read; and further, that the ability to perceive the spatial locations of letters, and the ability to perceive their shapes may be mediated by different brain regions (Mason and Katz, 1976, p. 347).

In my opinion this latter day version of the perceptual deficit theory of dyslexia is not very compelling. While there is little doubt that poor readers do not acquire the degree of sensitivity to orthographic redundancies characteristic of normal readers, there is no reason to equate such difficulty with central nervous system dysfunction. It would seem more to the point to suggest that the failure to become aware of letters in recurrent spatial locations is a consequence rather than a cause of reading disability, which obviously implies that the disorder has a different origin. Furthermore, the fact that poor readers manifested inefficiency in making use of spatial redundancy with non-alphabetic as well as alphabetic material, does not necessarily support the authors' theory, because the development of the disposition to search for invariance, and the acquisition of efficient strategies for doing so, may be a by-product

of successful reading, which transfers positively to the processing of non-alphabetic material. Indeed, Mason (1975) herself produces evidence that poor readers are characterized by a "plodding" left-right approach to the processing of letters in both words and pseudo-words, while normal readers seem more disposed to parallel processing of such material. My point should be obvious, given that the probability of discovering and making effective use of spatial redundancy would seem to be greater when items in a given array are processed in parallel rather than serially. Thus in my opinion, the theory at issue is highly questionable, and clearly does not rest on a firm foundation.[3]

It should be apparent from the above review, that empirical evidence in support of the visual deficit theories of reading disability available in the literature is, at best tenuous. Those studies which have attempted to validate such theories are characterized, by sampling, methodological, and/or interpretive problems, and therefore do not make a convincing case for the theoretical position they were designed to evaluate. However, the more basic problem, as I indicated earlier, is that the theories themselves are ill-founded. To reiterate the major contention, it is my belief that reading is primarily a linguistic skill and that the demands upon the visual system are not nearly as great in reading as the demands upon the various components of language. This would lead to the expectation that visual discrimination problems would account for a relatively small amount of the difficulty encountered by poor readers, and that such difficulty could itself be considered a secondary manifestation of more basic problems in verbal encoding. Indeed, as noted earlier there is reason to believe (Liberman et al., 1971) that apparent spatial configuration errors (e.g., calling b d or was saw) are, in fact, naming and

labeling errors caused by the unavailability or inaccessibility of verbal information. These contingencies generate the specific prediction that poor readers would be no different than normals, on measures of visual encoding, if the effects of verbal encoding were controlled. A second prediction issuing from this point of view is that poor readers would be differentiated from normal readers on various measures of verbal processing, but not on measures involving non-verbal processing.

The above hypotheses were tested in a series of studies conducted by my colleagues and I, systematically assessing (1) the influence of verbal mediation on visual memory in poor and normal readers, and (2) group differences on measures of verbal and non-verbal learning. Three general research strategies were employed. One approach involved comparisons of reader groups on short term visual recall of letters, words and designs, when instructions to subjects were varied to facilitate attendance, either to the visual or verbal features of those stimuli. It was anticipated that the poor readers would perform as well as the normal readers on the visual encoding (graphic reproduction) of the stimulus materials, but not as well as the normals on the verbal encoding or naming of particular items. This prediction was in keeping with Gibson's (1971) contention that the featural attributes of words are apprehended sequentially, and hierarchically, attendance to one attribute (i.e., graphic features) momentarily precluding attendance to the others (i.e., semantic, syntactic, and phonologic).

A second approach was to compare disabled and non-disabled readers on measures of short and long term visual memory, employing a novel orthography to control for previous experience with letters and words. Poor and normal readers who had no experience with the orthography, were contrasted with a

group of normal readers who were familiar with the orthographic and linguistic components of the stimuli presented. It was predicted that the performance of children who were unfamiliar with the types of stimulus words presented would not differ, and that these children would not perform as well as those who were acquainted with such words.

A third approach involved the systematic comparison of dyslexic and normal readers on verbal and non-verbal learning tasks involving various sensory systems, including the visual modality. The expectation was that the dyslexics would be generally comparable to the normal readers on the non-verbal learning tasks, but would be less proficient than the normals on tasks involving a verbal component.

Reader groups were compared on the differential processing of the visual and verbal features of printed words in two separate investigations employing the first approach outlined above (Vellutino, Steger and Kandel, 1972; Vellutino, Smith, Steger and Kaman, 1975). Carefully selected samples of severely impaired and normal readers (ages 7 to 14) were given tachistoscopic presentations of words, unconnected letters and numerals each varying in number of items per set (3, 4, and 5). They were also presented with geometric designs and asked to graphically reproduce or copy each of these stimuli from memory. The verbal stimuli (words, unconnected letters and numerals) were presented again (tachistoscopically), but this time subjects were asked to pronounce each of the words which appeared, and immediately after, "spell out" their letters in correct order. They were also instructed to name the unconnected letters and numerals in correct order, when these configurations appeared.

- Figure 1 here -

In both of these studies, poor readers performed significantly better

in the visual recall of the verbal stimuli, than they did in the naming of those same stimuli. Furthermore, poor readers performed at a level comparable to the normal readers under the graphic reproduction condition, but not under the pronunciation or naming condition. The only exception occurred in the case of the poor readers at younger age levels (7 years), who did not perform as well as their normal reading peers in copying the five letter sets, presumably because these stimuli began to tax the upper limits of visual short term memory (Miller, 1956; Simon, 1972). On the other hand, poor readers at older age levels (11 to 12 years), copied all stimulus sets as well as the normal readers at those same age levels, and better than the younger children, including those in the normal reader group. This was a particularly impressive finding in the case of the word stimuli, since the older poor readers could spell out the letters in given words better than the normal readers at the younger age levels, in spite of the fact that they pronounced those words no better (and in some cases worse) than the normals. This of course is a strong bit of evidence that the difficulty poor readers consistently encounter in word decoding is in the retrieval of the verbal constituents of printed words, and not in the discrimination of their visual features. The results can also be taken to mean that the older poor readers had more knowledge of the orthographic structures of the words presented, than did the poor and normal readers at younger age levels.

Put another way, the data suggest that the visual perception of a letter or word is not necessarily reflected in the labeling and naming of these items. More simply, when a child sees a b and calls it d or was and calls it saw, his errors are not caused by inaccuracy in perceiving these stimuli, but because he can't remember their names.

Reinforcing the above conclusion is the observation that poor readers did not differ from normal readers on the reproduction of the geometric designs. These findings, combined with the results discussed above, seriously undermine the perceptual deficit theory of reading disability.

The latter conclusion is even more strongly supported by the results of the second series of studies undertaken in our laboratory, comparing dyslexic and normal readers on visual recall of words taken from Hebrew (see figure 2).

Two of the studies in this series (Vellutino, Pruzek, Steger and Meshoulam, 1973; Vellutino, Steger, Kaman and DeSetto, 1975) evaluated immediate visual recall of Hebrew words in poor and normal readers, and a third compared these groups on both short and long term recognition of unconnected Hebrew letters (Vellutino, Steger, DeSetto and Phillips, 1975). The subjects were poor and normal readers (ages 7 to 12) who had no previous experience with Hebrew; and children at the same age and grade levels, who were learning to speak, read and write the language.

- Figure 2 here -

The experimental task in the first two studies presented subjects with three, four and five letter Hebrew words, each stimulus being observed for as many seconds as there were letters in a particular word. Subjects were simply asked to reproduce the letters in each word in correct order, after the stimulus was terminated. As predicted, there were no substantial differences between impaired and normal readers on the reproduction of the letters in the Hebrew words in proper sequence. However neither group performed as well as the children learning Hebrew, except for the three letter words, on which the performance of all groups was comparable.

Of particular interest in these studies, is the observation that the poor and normal readers, who had not been previously acquainted with Hebrew, manifested comparable tendencies to scan the stimulus words in a left-right direction. This was evident in the greater incidence of omission errors at the right terminal positions of the words, than at any other location. Especially striking, is the fact that the location and number of these errors was in close correspondence in poor and normal readers unfamiliar with Hebrew. In contrast, children who were learning to read Hebrew made most of their omission errors at the left terminal positions of the word stimuli, consistent with the right-left direction in which Hebrew letters and words are ordered. These data, are, of course, contrary to the view (Orton, 1937; Hermann, 1959) that poor readers are unable to establish a firm directional set because of spatial confusion.

Consistent with the above findings are the results of the third study in the series. This particular investigation assessed long term memory for unconnected Hebrew letters in reader groups (Hebrew and non Hebrew) constituted in accord with sampling criteria employed in the first two studies in this series. Subjects were presented with one, two, and three Hebrew letters, and thereafter asked to recognize these same stimuli among a group of distractors on three separate occasions: <u>immediately after presentation</u>, <u>twenty four hours later</u> and <u>six months later</u>. Poor and normal readers who were unfamiliar with the Hebrew letters prior to initial testing, were comparable on the recognition task under all three experimental conditions. However these two groups did <u>not</u> perform as well as the children acquainted with Hebrew, except for the six-month delay condition on which all groups were equivalent. Especially impressive in this study was the observation that a significant (and approximately equal)

number of children in each of the groups recognized a significant (beyond chance) number of these stimuli, even after six months. Thus the range of individual differences in long term visual recognition would appear to be no different in poor as compared with normal readers.

It should be noted that these findings are in contrast with those obtained in the studies by Lyle and Goyen mentioned earlier, which typically employed visual recognition tasks involving immediate and delayed memory. However, in the latter investigations, stimuli were exposed for very brief durations (along the order of milliseconds), thereby requiring rapid coding of visual stimuli for later recollection. But in the present study, subjects had ample time to synthesize and visually encode each of the stimulus sets, and this may have accounted for the disparity in findings. Indeed, it is under conditions characterized by limited time for processing that the ability to employ verbal codes has particular utility. We have already suggested that poor readers have difficulty in employing such codes and the point we are making here should be apparent.

Additional support for our position is provided by studies which systematically compared severely impaired and normal readers on measures of verbal and non-verbal learning — the third research strategy outlined above. In several related investigations (Steger, Vellutino and Meshoulam, 1972; Vellutino, Steger and Pruzek, 1973; Vellutino, Steger, Harding and Phillips, 1975; Vellutino, Harding, Phillips and Steger, 1975; Vellutino, Bentley, Phillips, 1978), poor readers uniformly performed below the level of normal readers on paired associates learning involving either meaningful or non-meaningful words. In contrast, the reader groups were equally adept in learning to associate non-verbal representations. Since most of these contrasts involved visual symbols, we feel confident in concluding that

poor readers do not experience any more difficulty than normal readers in visual association learning, except insofar as such learning involves verbal processing.

Of special interest, in the present context, are the format and materials employed in one of the studies in this series. The major intent of this investigation was to compare the differential performance of poor and normal readers (ages 9 - 12) on the coding of patterned information involving either visual-verbal paired associates learning, or visual-visual association learning. A transfer of training paradigm was designed to simulate the positive transfer which must implicitly occur when the child learns to make effective use of grapho-phonemic invariance, as, for example, when he learns cat, rat and ran as sight words, and spontaneously decodes can. Thus the initial training task paired bi-syllabic nonsense words with novel visual symbols, each of the syllables in a given word being paired with a different visual symbol (see figure 3). The transfer task presented subjects with the same universe of syllables and visual symbols presented in initial acquisition, but in completely different combinations. This procedure was meant to be analogous to the recombinatory use of the orthographic and phonetic constitutents of words derived from an alphabet. A visual analogue of this task was designed to evaluate generalization learning and pattern coding in the visual modality, and comparably selected subjects were randomly assigned either to the visual-verbal or visual-visual coding conditions (see figure 4).

- Figures 3 and 4 here -

It was found that poor readers did not perform as well as normal readers on the visual-verbal coding task, either under the training or transfer conditions. However, the groups were equivalent on both visual-

visual training and transfer. Furthermore, when individual variability on the visual-verbal training scores was held constant, group differences on transfer became negligible. This latter finding suggests that the difficulty encountered by poor readers in learning to generalize visual-verbal relationships, is related to more basic dysfunction in initial acquisition of such relationships and not to deficiency in processing patterned information. Thus, the differential performance of the poor readers on the major stimulus conditions involved in the study obviously implies that such children sustain no basic disorder in visual pattern coding; and further, that they experience significant difficulty in acquiring coded relationships that involve the processing of linguistic stimuli.

In my opinion, the results of this study, of all we have conducted, represent the most convincing bit of evidence that reading disability is not caused by deficiencies in visual perception and visual memory, given: (1) the complexity of the visual processing required of subjects in the study, (2) the nature of the tasks employed, particularly insofar as they involved the acquisition of categorical relationships and not simply rote learning, and (3) the random assignment of poor and normal readers to visual and visual-verbal learning conditions, on which they performed differentially. Indeed, these data coupled with the results of the other studies conducted in our laboratory, strongly contraindicate visual deficit theories of reading disability; and, as important, constitute both direct and indirect support for our contention that this difficulty is caused either by deficiencies in various aspects of linguistic functioning, or by a specific disorder in visual-verbal association learning. I have discussed these latter possibilities in greater detail elsewhere (Vellutino, 1977,

Vellutino, in Press), and Dr. Perfetti specifically addresses the relationship between verbal encoding and reading disability at this conference. Suffice to say for present purposes that recent studies have provided evidence that reading problems in otherwise capable children may be associated with select impairments in semantic, syntactic and phonologic processing, implicating respective deficiencies in such important abilities as knowledge of words, word storage and retrieval, comprehension of various syntactic constructions, verbal concept formation, phonetic encoding of both verbal and non-verbal material, verbal fluency and expressive language in general.

Specific disorder in visual-verbal integration may constitute a qualitatively different source of reading disability, characterized by a circumscribed dysfunction in the cross-referencing of visual and linguistic information. Such difficulty could theoretically occur, either because of dysfunction in the flow of information between the hemispheres, or because of a disruption in the transduction of visual and verbal information within the hemisphere which primarily supports language. The results of the paired associates studies referenced above would be consistent with either of these possibilities, but the distinction between them, and their respective utility as viable explanations of reading disability is dependent upon future research.[4]

In any event, the study of verbal processing deficits in poor readers is in its infancy, but initial research results appear to be promising and continued exploration of this problem area is certainly worthwhile.

Summary

The present paper addressed the popular view that dyslexia or specific reading disability, is caused by dysfunction in visual perception, and

visual memory, presumably associated with developmental difficulties of basic constitutional origin. Specific reading disability can be found to occur in children who are normal in other respects — that is, those who sustain severe reading impairment in spite of average or above average intelligence, the absence of gross sensory, physical, neurological, or emotional and social disorder, socio-cultural advantage, and adequate opportunity for learning. Reading disorder in children of this description has been most often ascribed to deficient form perception, spatial and directional confusion, and dysfunction in figure-ground perception. However, some investigators have more recently suggested that poor readers sustain perceptual abnormalities of other types, citing specific anomalies in the speed with which such children process visual information, the duration of the visual after image, and the ability to "perceive" and make use of the redundancies inherent in English orthography. Studies testing hypotheses concerned with each of these respective problem areas have typically employed figure-drawing, visual matching and figure-ground tests to evaluate given functions, in addition to visual search tasks comparing poor and normal readers on both speed and accuracy of processing.

The results of most of these studies were equivocal and inconclusive, owing to sampling, methodological and interpretive problems. Many failed to control for reader group differences in previous experience and/or deficiencies in specific functions such as verbal or motor skills, and most employed procedures which confounded discrimination with short term memory processes.

And while virtually all perceptual deficit theories of reading disability implicate dysfunction in the initial or sensory storage stage

of visual information processing (i.e., during the first 300 milliseconds) only a few investigations have evaluated these theories employing procedures which directly assess initial stage processing. The results of these studies were conflicting, but the majority of those conducted yielded no substantial evidence that poor readers differ from normal readers in analysis and synthesis of visual forms.

The more recent suggestion of some authors that poor readers sustain a specific deficiency in "perceiving" spatial redundancy was rejected on interpretive grounds, and it was concluded that the evidence supporting the visual deficit theories of reading disability which have appeared in the literature is not compelling.

However, the strongest contraindication to these theories emerges in a series of studies conducted in our own laboratory which uniformly found no differences between poor and normal readers on tests of short and long term visual memory, when the effects of verbal mediation were minimized. Poor readers also performed as well as normal readers on a variety of non-verbal learning tasks which, in some instances involved only visual stimuli. In contrast, they consistently performed below the level of normal readers on tasks which involved a verbal component. These data constitute strong evidence that reading disability is not associated with dysfunction in visual processing. Instead they support the contention that the disorder is caused either by dysfunction in one or more aspects of linguistic functioning, or by specific impairment in visual-verbal learning. In fact our own findings, the results of several studies which have recently appeared in the literature evaluating verbal functioning in poor readers, and the nature of the reading process itself, has led me to believe that continued exploration of verbal deficit explanations of dyslexia constitute the most

promising avenue for additional study of reading problems in young children; and, further, that visual deficit theories of reading disability will ultimately be discarded.

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Footnotes

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[2]The terms dyslexia and specific reading disability are employed herein because of their widespread use in reference to children with severe reading impairment who are apparently normal in other respects. They are therefore intended to refer only to children of this description. In this paper such rubrics as "dyslexia," "specific reading disability," "reading disability," "poor reader" and like terms are used interchangeably.

[3]We can reinforce the above conclusions by pointing out that the poor readers in the Mason and Katz (1976) study differed only on latency measures and not on the accuracy with which they located target stimuli. Furthermore, the studies referenced did not control for intelligence and other exclusionary variables,nor did they employ stringent achievement criteria. Thus, their results can also be questioned on the basis of inadequacies in sampling.

[4]A study recently completed in our laboratory (Vellutino, Bentley and Phillips, 1978) in fact evaluated the possibility that reading disability may be associated with dysfunction in interhemispheric transmission. Carefully selected samples of poor and normal readers (stratified at grades 2 and 4) were given unilateral field presentations of novel visual stimuli, and asked to associate each stimulus with a meaningful word. A transmission

deficit explanation of coding and decoding problems generates the prediction that the reader groups would be differentiated only on left visual field (right hemisphere) presentations. Contrary to this prediction the groups differed on both visual field presentations, suggesting the possibility of left hemisphere or linguistic dysfunction as the cause of these differences -- that is, given that the subjects' responses were verbal and were therefore processed by the hemisphere supporting language. However, because these results have not yet been replicated, and given the fact that tests of this hypothesis are at a seminal stage, we prefer to adopt a conservative position and suggest that a transmission deficit explanation of reading disorder may yet be viable.

REAL WORDS

Three Letter	Four Letter	Five Letter
fly	loin	blunt
bed	form	drawn
was	calm	chair

SCRAMBLED LETTERS

Three Letter	Four Letter	Five Letter
dnv	jpyc	ztbrc
hbd	gzfs	yfpqg
mcw	qvlt	qldnr

NUMBERS

Three Digit	Four Digit	Five Digit
382	4328	96842
974	3724	31579
296	9156	86314

GEOMETRIC DESIGNS

Two Items **Three Items**

Figure 1
Verbal and non-verbal stimuli employed in the study

Figure 2

Hebrew words presented to poor and normal readers for immediate visual recall. Reproduced with permission of the editor from Cortex, IX, 1973.

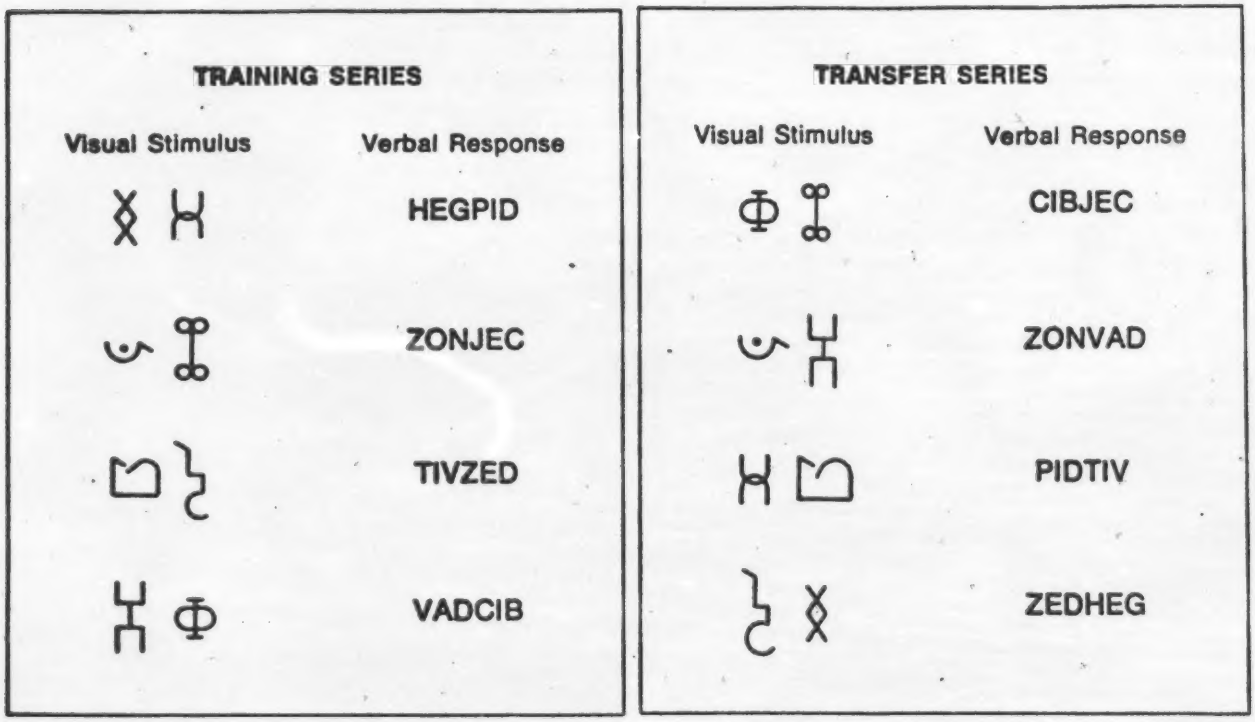

FIGURE 3

VISUAL-VERBAL CONDITION: STIMULI AND RESPONSES FOR THE TRAINING AND TRANSFER SERIES

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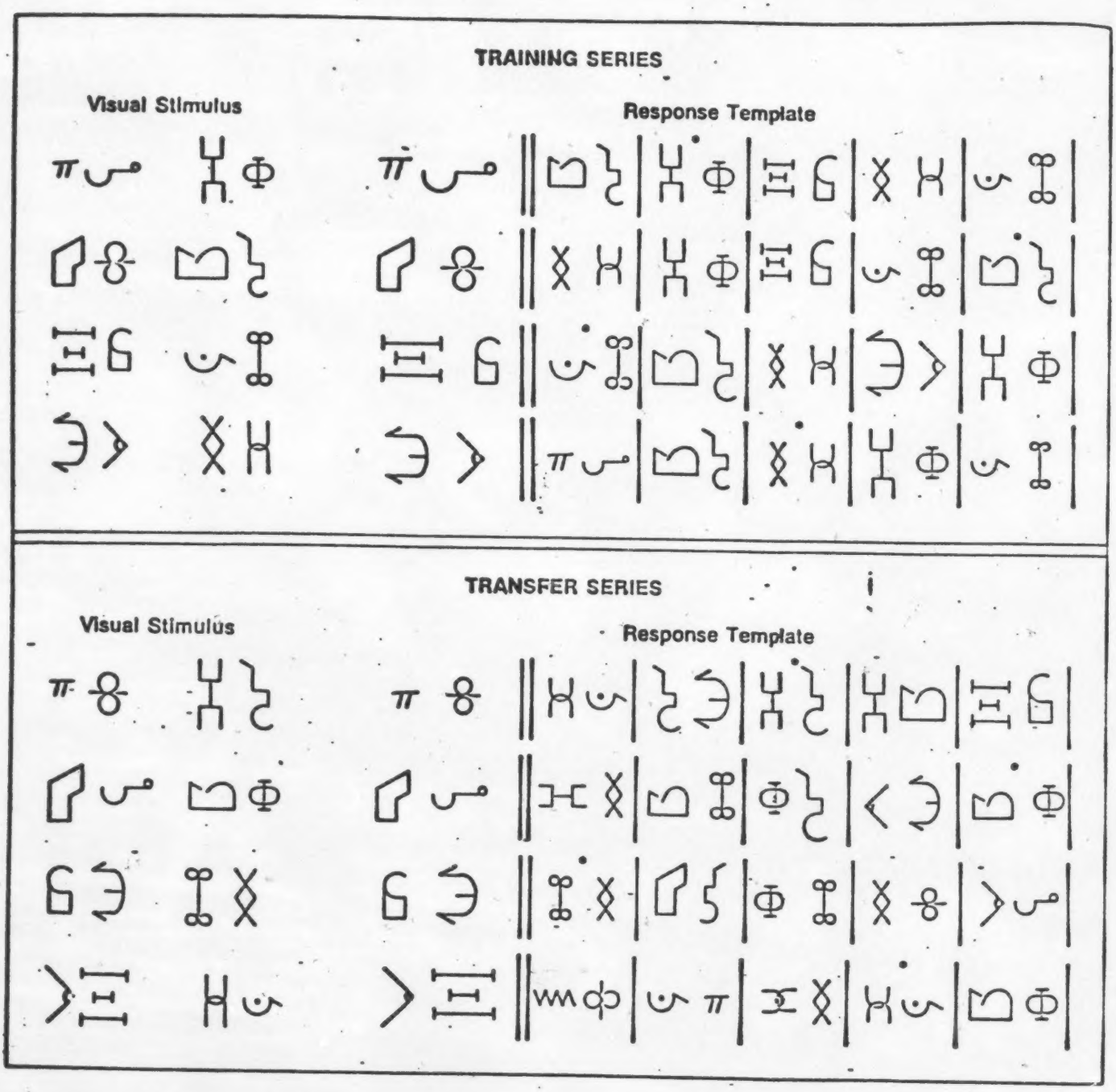

*denotes correct response.

Figure 4
Visual-Visual Stimuli and Response Templates. Reproduced with permission of the editor from The Journal of Genetic Psychology, **Vol. 126, 1975.**